FLEXIBLE RADIO LINK
CONTROL PROTOCOL

CROSS-REFERENCES TO RELATED APPLICATIONS

This Application for Patent claims the benefit of priority

from, and hereby incorporates by reference the entire disclosure

of, co-pending U.S. Provisional Application for Patent Serial

5   No. 60/128,663, filed April 9, 1999.

BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention relates in general to the telecommunications field and, in particular, to a flexible Radio Link Control (RLC) protocol for a mobile communications system.

Description of Related Art

When data is conveyed between nodes in a telecommunication network, certain algorithms are used to recover from the transmission of erroneous data and the loss of data on the transmission links between the nodes. An algorithm commonly used to recover from the transmission of erroneous data is referred to as an Automatic Repeat Request (ARQ) protocol.

The existing ARQ protocols include two peer entities that communicate with each other over transmission links. Each such entity includes a receiver and a sender. The units of data conveyed between the peer entities are commonly referred to as Protocol Data Units (PDUs). The ARQ protocols include certain

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rules for sending and receiving PDUs, as well as rules for the structure of the PDUs.

The receiver can inform the sender about which PDUs were correctly received (i.e., receiver acknowledges correctly-received PDUs) and/or which PDUs were incorrectly received. When the sender receives this information, it retransmits the "lost" PDUs. In other words, an ARQ protocol is a set of rules that allow the use of efficient retransmission mechanisms between a sending side and receiving side in a communication system. These rules specify, for example, how and in what form the PDUs are to be constructed so that the receiving side can interpret the conveyed PDUs correctly and respond to them accordingly.

Three main types of information elements (PDUs) can be transferred between two ARQ peer entities: user data; error recovery control data; and common control data. These three types of PDUs can be found in all existing ARQ protocols. A user data PDU contains at least user data and a sequence number.

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An error recovery control data PDU contains various amounts of control information needed for error recovery, and control functions such as positive and negative acknowledgments. A common control data PDU contains common control data. Notably,

5　PDUs that include user data and at least a sequence number are denoted herein as Data-PDUs (D-PDUs), and PDUs that include control data needed for error control/recovery are denoted herein as Status-PDUs (S-PDUs).

In the known High Level Data Link Control (HDLC) protocol,

10　which forms the basis for many existing ARQ protocols, the three types of PDUs are called, respectively, information frames (I-frames), supervisory frames (S-frames), and unnumbered frames (U-frames). The RLC protocol used in the existing General Packet Radio Service (GPRS) and the so-called 3rd Generation

15　Cellular Communication System is an example of an HDLC-derived ARQ protocol.

In most communication systems, user data information is conveyed in both directions between the peer entities. A common

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feature included in an ARQ protocol is that is possible to include error control information in user data PDUs. This capability is known as "piggybacking". For example, an acknowledgment is included in all I-frames (i.e., D-PDUs) of

5   HDLC-derived protocols. The acknowledgment informs the peer entity about the sequence number of the last (in-sequence) correctly received PDU.

The 3rd Generation Partnership Project (3GPP™) has produced an RLC Protocol Specification for the Radio Access Network (RAN)

10   in the so-called 3rd Generation Digital Cellular Telecommunications System. This system is also known as the Universal Mobile Telecommunication System (UMTS), the UMTS Terrestrial Radio Access (UTRA) system, and the International Mobile Telecommunications-2000 (IMT-2000) system. As such, in

15   accordance with the RLC Protocol Specification for the 3rd Generation System, the RLC sublayer provides three, different data transfer service modes (modes for services that the RLC layer provides to the higher layers): (1) transparent data

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transfer; (2) unacknowledged data transfer; and (3) acknowledged

data transfer. The transparent data transfer service transmits

higher layer PDUs to a peer entity without adding any protocol

information to these PDUs. The unacknowledged data transfer

5   service transmits higher layer PDUs to a peer entity, but

without guaranteeing delivery to the peer entity involved.

The acknowledged data transfer service provided by the RLC

Protocol transmits higher layer PDUs to a peer entity with

guaranteed delivery. If the RLC sublayer is unable to deliver

10   such data correctly (e.g., error-free delivery), the RLC user at

the transmitting side is so notified, and that data is

retransmitted. As such, in accordance with the RLC protocol,

the acknowledged data transfer mode provides error-free delivery

(ensured by retransmission). In other words, the receiving RLC

15   peer entity delivers only error-free SDUs to the higher layer.

The acknowledged data transfer mode also provides unique

delivery (the RLC sublayer delivers an SDU only once to the

receiving upper layer), and in-sequence and out-of-sequence

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delivery (the RLC sublayer delivers SDUs to the receiving higher layer entity either in the same order or in a different order than what the transmitting higher layer entity submits to the RLC sublayer).

5   A significant problem with the existing RLC protocol is that only one protocol configuration is specified. Consequently, this protocol is not readily adaptable to the relatively large number of different service situations that can occur in existing and future multi-service systems. However, as

10   described in detail below, the present invention successfully resolves this problem and other related problems.

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SUMMARY OF THE INVENTION

In accordance with a preferred embodiment of the present invention, a flexible RLC protocol for a mobile communication system is provided, whereby a plurality of different RLC functions are defined. These different RLC functions can be combined in a number of different ways to produce a complete and functional, but more flexible RLC protocol than the existing protocol. For example, a new set of rules are provided for determining how and/or when to poll for, or send, a status report for ARQ purposes. As such, for a specific service configuration, one set of the rules can be used, and for a different service configuration, another set of the rules can be used. In this way, the rules can be conformed suitably to the type of service involved. For example, it may be preferable to use periodic polling for one type of service, and no polling for another type of service. The present invention's protocol allows flexible configuration on a per service basis.

An important technical advantage of the present invention is that a flexible RLC protocol is provided, which can readily adapt to the multitude of different service situations that can occur in a multi-service communication system.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the method and apparatus of the present invention may be had by reference to the following detailed description when taken in conjunction with the accompanying drawings wherein:

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FIGURE 1 is a diagram that illustrates an acknowledged mode data transfer method for an RLC protocol, which can be used to implement the preferred embodiment of the present invention.

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DETAILED DESCRIPTION OF THE DRAWINGS

The preferred embodiment of the present invention and its advantages are best understood by referring to FIGURE 1 of the drawings, like numerals being used for like and corresponding

5   parts of the various drawings.

Essentially, in accordance with a preferred embodiment of the present invention, a flexible RLC protocol for a mobile communication system is provided, whereby a plurality of different RLC functions are defined. These different RLC

10   functions can be combined in a number of different ways to produce a complete and functional, but more flexible RLC protocol than the existing protocol. For example, a new set of rules are provided for determining how and/or when to poll for, or send, a status report for ARQ purposes. As such, for a

15   specific service configuration, one set of the rules can be used, and for a different service configuration, another set of the rules can be used. In this way, the rules can be conformed suitably to the type of service involved. For example, it may

be preferable to use periodic polling for one type of service, and no polling for another type of service. The present invention's protocol allows flexible configuration on a per service basis.

5   Specifically, FIGURE 1 is a diagram that illustrates an acknowledged mode data transfer method, which can be used to implement the preferred embodiment of the present invention. Although an acknowledged mode data transfer method is shown, the present invention is not intended to be so limited and can

10   include other data transfer methods or other data retransmission protocols. As shown, the acknowledged mode data transfer method can be used for transferring data between two peer entities which are operating in the acknowledged mode. In accordance with the existing RLC protocol, this method can be initiated by

15   either the User Equipment (UE) or the UTRA Network (UTRAN). As such, the sender in the UE or UTRAN sends one or more Acknowledged Mode Data PDUs (AMD PDUs) to the receiver in the UTRAN or UE. An AMD PDU is used to convey sequentially-numbered

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PUS containing RLC SDU data. The AMD PDU is used by the RLC when it is operating in the acknowledged mode. An AMD PDU includes a segment of one or more SDUs, a D/C field (indicating a D-PDU), a sequence number, a polling bit, a header extension

5   bit, and one or more length indicator fields.

For this exemplary embodiment, the RLC functions are divided into two groups: transmitting (sending) side functions; and receiving side functions. All such functions can be implemented by the UE (e.g., mobile station) or the UTRAN. A

10 transmitting or receiving RLC function can be mandatory or optional to use for each acknowledged mode entity. If such a function is mandatory, then no explicit signalling (e.g., from the Radio Resource Control (RRC)) is needed to initiate that function.

15   Referring to the RLC transmitting functions, if a polling mechanism is applied on the transmitting entity side, the following Table (1) illustrates the functions that control when a transmitter can poll a peer entity for a status report. As

such, an S-PDU transfer method is used for transferring status

information between two RLC peer entities which are operating in

the acknowledged mode. The method can be initiated by either

the UE or UTRAN.

Trigger	Presence
Last PDU in buffer.	Mandatory
Poll timer.	Mandatory
Every X PDU.	Optional
Every X SDU.	Optional
X% of transmission window.	Optional
Timer based.	Optional
$T_{prohibit}$	Optional

TABLE 1.

Table 1 illustrates the functions that can trigger when a

transmitter polls the receiver for a status report. One such

trigger event is when the last PDU in the transmission buffer is

transmitted. As shown in Table 1 for this embodiment, the

transmission of the last PDU in the transmitter buffer function

is mandatory for the transmit side when polling has been

applied.

Another function that can trigger when a transmitter polls

the receiver for a status report is by use of a poll timer. The

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poll timer starts timing when a poll is transmitted to the peer

entity. If no status report is received by the transmitting

entity before the poll timer has expired, the transmitter sends

a new poll to the receiver. The value of the timer is

5   determined by a signal from the RRC. For this embodiment, the

poll timer function is mandatory for the transmitting side if

polling has been applied.

The transmitting side can also poll the peer entity for a

status report every X PDU. The value of X is determined by a

10   signal from the RRC. For this embodiment, this function is

optional for the transmitting side. Similarly, the transmitting

side can poll the peer entity for a status report every X SDU.

Again, the value of X is determined by a signal from the RRC,

and this function is optional for the transmitting side.

15   The transmitting side can also poll the peer entity for a

status report when the transmitter has reached X% of the

transmission window. The value of X is determined by a signal

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from the RRC, and this function is optional for the transmitting side.

Another function that can trigger when a transmitter polls the receiver for a status report can be based on the use of a

5   timer. In other words, the transmitting side polls the peer entity periodically for a status report. The value (duration) of the time period is determined by a signal from the RRC. This function is optional for the transmitting side.

A $T_{prohibit}$ function can be used to control how often the

10   transmitting side is allowed to poll the peer entity. The $T_{prohibit}$ timer is started when a poll is transmitted to the peer entity. As such, the transmitting entity is not allowed to poll the peer entity while the $T_{prohibit}$ timer is running. The value (duration) of the timer is determined by a signal from the RRC.

15   This function is optional for the transmitting side.

Table 2 illustrates a list of functions that can control how an entity can react to a received status report, in accordance with the preferred embodiment of the present

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invention. A function that controls the transmitting side's

reaction to a status report is the adjustment or updating of the

transmission window according to the information received in the

status report. This function is mandatory for the transmitting

5   side.

Trigger	Presence
Adjust transmission window.	Mandatory
Retransmit PDUs.	Mandatory
Plausibility check.	Optional

TABLE 2.

Another function that controls the transmitting side's

reaction to the receipt of a status report is the transmitting

side's retransmission of the AM PDUs that have been requested by

10   the status report. If a plausibility check function has not

been applied, then the requested AM PDUs are retransmitted

immediately and with a higher priority than that of the newer AM

PDUs. This function is mandatory for the transmitting side.

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The above-mentioned plausibility check is another function that can be used to control the reaction of the transmitting side in response to the receipt of a status check. Essentially, a plausibility check determines whether the contents of a status report are reasonable or not. This function can prohibit or delay the retransmissions requested in the status report. For example, the status report can contain negative acknowledgments for PDUs which may not have arrived at the receiver before the status report was transmitted. As such, the transmitter should not retransmit these PDUs. This function is optional for the transmitting side.

In accordance with the preferred embodiment, the RLC functions for the receiving side are now described. Essentially, the receiving side sends a status report to the transmitting entity if the receiving side receives a poll. The status report is transmitted to the transmitting side immediately, except if the Estimated PDU Counter (EPC) is running. The EPC is a counter that is decremented each

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transmission time interval with the estimated number of PUs that should have been transmitted during that interval. If a receiver detects missing PDUs, the receiver sends an S-PDU to the transmitter and sets the EPC equal to the number of

5   requested PUs. The EPC timer controls the maximum amount of time that the EPC has to wait before it starts counting down. When the EPC count reaches zero and not all requested PUs have been received correctly, a new S-PDU is transmitted and the EPC is reset accordingly. The EPC timer is then restarted. As

10   such, in accordance with the preferred embodiment, if the EPC counter is used and running, the status report is transmitted to the transmitting side when the EPC counter has expired. This function is mandatory for the receiving side.

Table 3 illustrates the functions that can control just

15   when the receiving entity is to transmit a status report to the transmitting side, in accordance with the preferred embodiment of the present invention. One such control function at the receiving side is the receipt of a poll. As such, the receiving

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side sends a status report to the peer entity upon receipt of a poll. The status report is sent immediately to the transmitting side, except when the EPC counter is running. If the EPC counter is being used and running, the receiving side sends the status report after the EPC counter has expired. This function is mandatory for the receiving side.

Trigger	Presence
Reception of poll.	Mandatory
EPC	Optional
Detection of missing PDU(s).	Optional
Every X SDU.	Optional
Every X PDU.	Optional
X% of receiving window.	Optional
Timer based.	Optional
$T_{prohibit}$	Optional

TABLE 3,

For this embodiment, the EPC counter is started when a status report is transmitted to the peer entity. If the EPC counter expires before all of the AM PDUs requested for retransmission have been received at the receiving side, then the transmitting side transmits a new status report to the peer entity. The EPC counter function is optional for the receiving side.

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Another function that controls just when the receiving side

is to send a status report to the transmitting side is the

detection of missing AM PDUs. If the receiving side detects

missing AM PDUs, the receiving side transmits the status report

5   immediately, except when the EPC counter is running. If the EPC

counter is in use and has been running, the receiving side

transmits the status report to the transmitting side after the

EPC counter has expired. This function is optional for the

receiving side.

10   The receiving side can also send a status report to its

peer entity every X SDU. The value of X is determined by a

signal from the RRC. For this embodiment, this function is

optional for the transmitting side. Similarly, the receiving

side can send a status report to the peer entity every X PDU.

15   Again, the value of X is determined by a signal from the RRC,

and this function is optional for the receiving side.

The receiving side can also send a status report to its

peer entity when X% of the transmission window has been reached.

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The value of X is determined by a signal from the RRC, and this function is optional for the receiving side.

Another function that can control just when the receiving side sends a status report to its peer entity can be based on the use of a timer. In other words, the receiving side sends the status report periodically to the peer entity. The value (duration) of the time period is determined by a signal from the RRC. This function is optional for the receiving side.

A $T_{prohibit}$ function can also be used to control how often the receiving side is allowed to send a status report to the peer entity. The $T_{prohibit}$ function is started when a status report is transmitted to the peer entity. As such, the receiving side is not allowed to send status reports to the peer entity while the $T_{prohibit}$ timer is running. The value of the timer is determined by a signal from the RRC. This function is optional for the receiving side.

In accordance with the preferred embodiment, different combinations of the above-described RLC functions can be used to

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satisfy retransmission requirements for an ARQ protocol in a more flexible manner than that achieved by the existing protocol. For example, in order to achieve the retransmission scheme set forth in the existing RLC Protocol in a more flexible

5   manner, the following (e.g., acknowledged mode) settings can be signalled by the RRC: (1) Polling should be used; (2) Poll the peer entity every SDU (X=1); (3) $T_{prohibit}$ should be used on the transmitting side; and (4) A status report is transmitted immediately upon detection of one or more missing PDU(s). In

10   addition, the following functions are provided implicitly because they are mandatory: (1) Poll when the last PDU in the transmitter buffer has been transmitted; (2) Poll timer should be used; (3) The transmitting side adjusts the transmission window in accordance with the received status reports; (4) The

15   transmitting side retransmits AM PDUs in accordance with the received status reports; and (5) The receiving side replies immediately with a status report upon receiving a poll.

Also in accordance with the preferred embodiment, the following is another example that illustrates how the above-described RLC functions can be used to satisfy retransmission requirements for an ARQ protocol in a more flexible manner than

5 that achieved by the existing protocol. In order to achieve the retransmission scheme using the EPC counter mechanism in a more flexible manner, the following (e.g., acknowledged mode) settings can be signalled by the RRC: (1) Polling should be used; (2) Poll when the transmitting side has reached X% of the

10 transmission window; (3) The receiving side should use the EPC counter mechanism; and (4) The status report is transmitted immediately upon detection of missing PDU(s), except when the EPC counter is running. In addition, the following functions are provided implicitly because they are mandatory: (1) Poll

15 when the last PDU in the transmitter buffer has been transmitted; (2) Poll timer should be used; (3) The transmitting side adjusts the transmission window in accordance with the received status reports; (4) The transmitting side retransmits

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AM PDUs in accordance with the received status reports; and (5) The receiving side replies immediately with a status report upon receiving a poll, except when the EPC counter is running.

Although a preferred embodiment of the method and apparatus

5   of the present invention has been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it will be understood that the invention is not limited to the embodiment disclosed, but is capable of numerous rearrangements, modifications and substitutions without

10   departing from the spirit of the invention as set forth and defined by the following claims.

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